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Exploring MRI Results

1. Introduction

The human brain is an intricate organ, subject to changes across the lifespan due to various factors including aging, disease, and environmental influences. Understanding these changes is crucial for advancing our knowledge in fields such as neurology, psychology, and gerontology. Magnetic Resonance Imaging (MRI) offers a non-invasive method to study the brain's structure and function in vivo, providing valuable data on brain volume, morphology, and changes over time. Among the measurable aspects derived from MRI data, the Estimated Total Intracranial Volume (eTIV) stands out as a significant indicator of brain health and aging. eTIV reflects the overall capacity of the cranial cavity, which can influence or be influenced by neurodegenerative diseases, cognitive decline, and other health factors. This analysis seeks to explore the dynamics of eTIV across different populations and over time, utilizing a dataset from a longitudinal study on individuals with and without dementia.

To investigate these dynamics thoroughly, we employ mixed-effects ANOVA, a statistical method well-suited for analyzing datasets with both fixed and random effects. This approach allows to account for individual variability while assessing the impact of categorical factors such as group membership (e.g., demented vs. nondemented) and temporal factors (e.g., visit times). By leveraging mixed-effects ANOVA, we aim to uncover patterns in eTIV and nWBV changes, providing insights into how the intracranial and brain's volume may vary due to disease progression, aging, or potentially other unidentified factors.

Our exploration will address three fundamental research questions:

- Research Question 1: Does eTIV vary across different visit times within individuals?
- Research Question 2: Does nWBV vary across different visit times within individuals?

2. Data Cleaning and Data Wrapping

The raw data has 16 columns with 296 entities (rows). After initial review of the datasets we were confident that not much data cleaning was deemed necessary for the analysis since we are not interested in those two columns named ‘SES’ and ‘MMSE’ which has missing values.

Observations and Considerations:

Since our analysis only focused on a few aspects, we want to work on the following columns. Below we provide a short description of each column:

id: unique identification number

Group: patients in this dataset are divided into different groups, which are stated as ‘Nondemented’, ‘Demented’, or ‘Converted’

Visit: times of visit, stated as 1 or 2

M/F: Sex, stated as M for male, or F for female

Age: age of patients

eTIV: Estimated Total Intracranial Volume

nWBV: Estimated Total Intracranial Volume

ASF: Atlas Scaling Factor

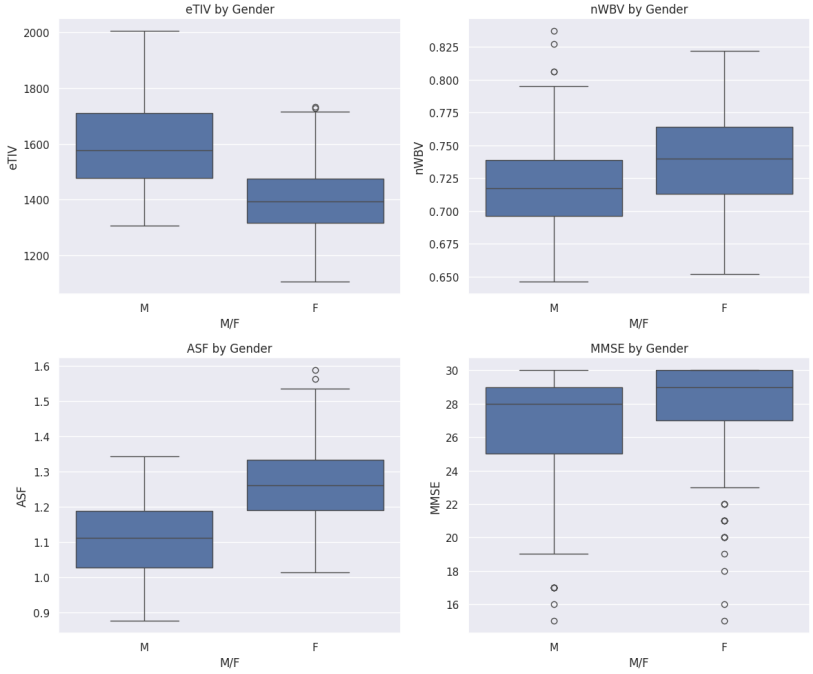
3. Exploratory Data Analysis (EDA)

In the process of EDA, we firstly find that there are some missing values in ‘SES’ and ‘MMSE’, but fortunately we are not interested in those variables so that we just delete the whole columns. And there are some other variables we also do not have interest so we delete 'Subject ID', 'MRI ID', 'MR Delay', 'Hand', 'CDR', and ‘EDUC’. Besides, we rename ‘Unnamed 0’ to ‘id’. Last but not least, we drop the null values again for the rest variables to avoid any mistakes in the further analysis.

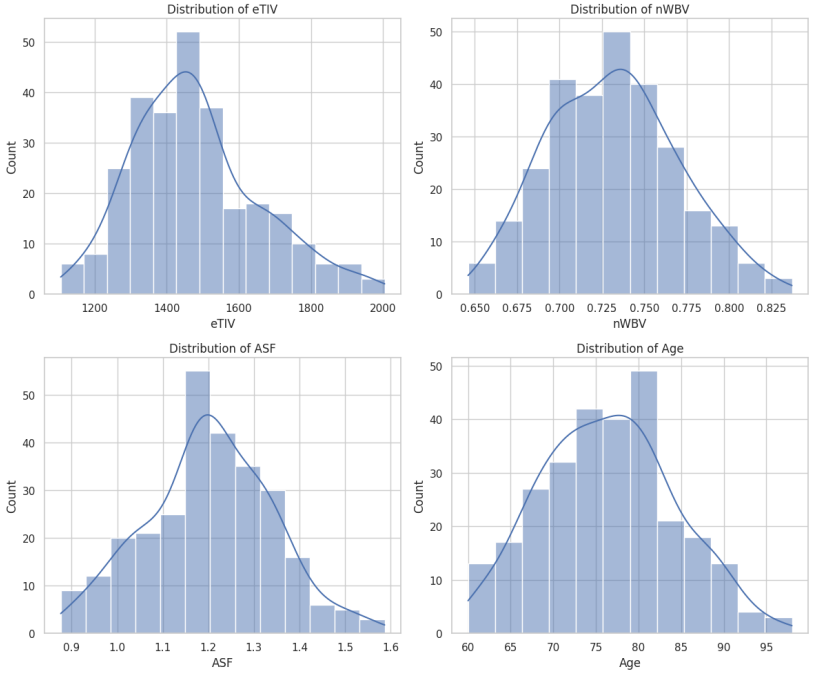
4. Interaction Plots

We firstly make 4 boxplots (Graph 1) compare gender distributions of eTIV, nWBV, ASF, and MMSE. Men show higher median eTIV, while women have higher nWBV and ASF values, with greater variability. MMSE scores are slightly higher for women, indicating possible gender-related differences in brain volume and cognitive function, though some outliers exist. Then, the histograms (Graph 2) display the distributions of eTIV, nWBV, ASF, and Age. eTIV and ASF show roughly normal distributions, with eTIV spread across a broad range of values, while ASF is more tightly clustered.

(Graph 1)



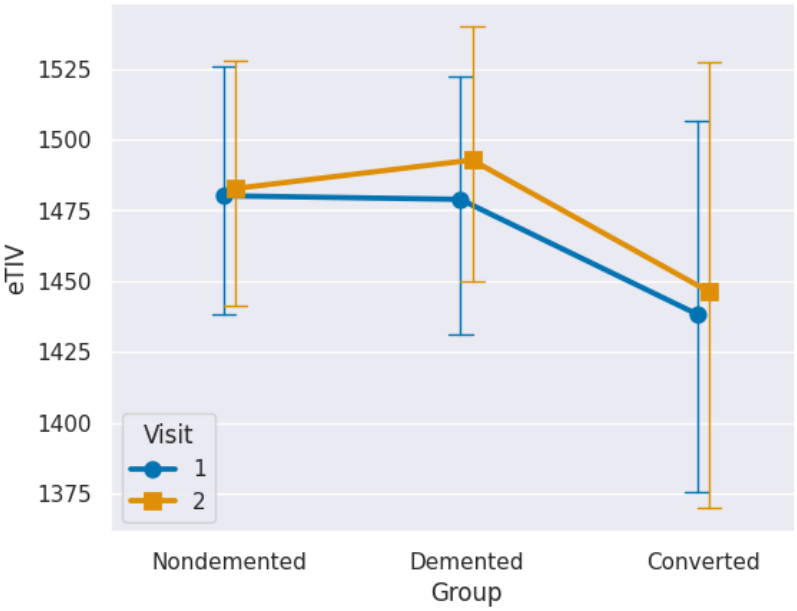
(Graph 2)

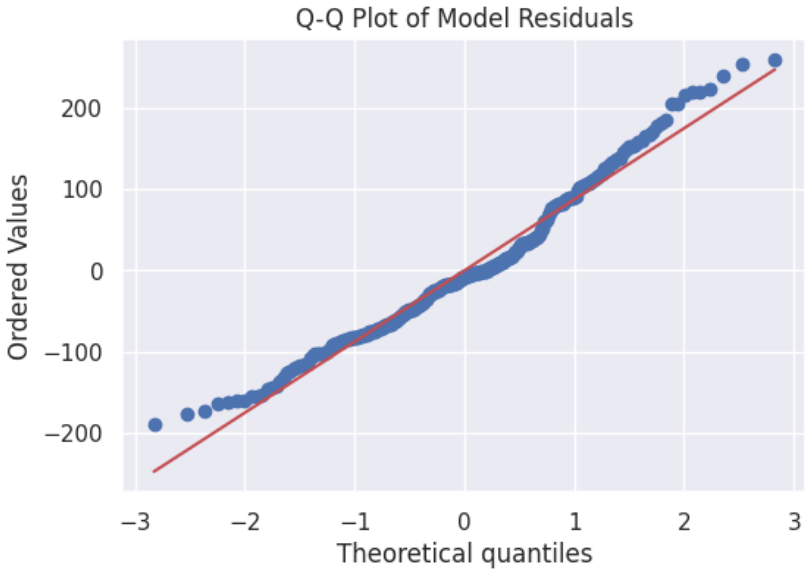


5. Mixd Effects ANOVA for eTIV

Research Question #1:Does eTIV vary across different visit times within individuals?

This line graph with error bars presents eTIV measurements across two visits for three groups: Nondemented, Demented, and Converted. The first visit is marked in blue, the second in orange. For the Nondemented group, there's a slight decrease in mean eTIV from Visit 1 to Visit 2. The Demented group shows a marginal increase in mean eTIV at the second visit, while the Converted group exhibits a significant decline. The error bars, representing variability within each group, suggest substantial overlap between visits for the Nondemented and Demented groups, indicating less change between visits. However, the Converted group's larger error bars at Visit 2 imply greater variability or perhaps a more heterogeneous response to conversion. The sharp downward trend for the Converted group could suggest that conversion (likely from nondemented to demented) is associated with a notable decrease in eTIV, potentially indicating progressive brain volume loss.





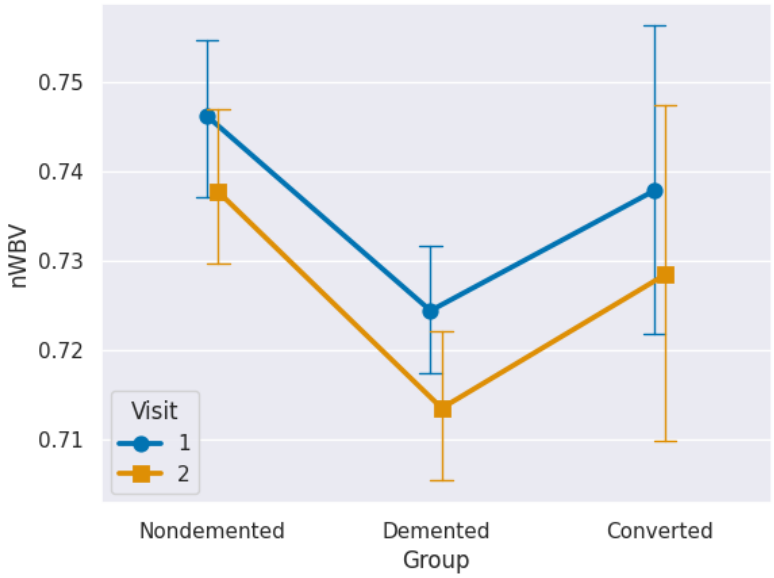
And then we check the assumptions, including homogeneity, sphericity, and normality of this mixed effects ANOVA. As the code shown in the ipynb file and the Q-Q plot shown above, we are confident to say that all three assumptions are satisfied in this analysis.

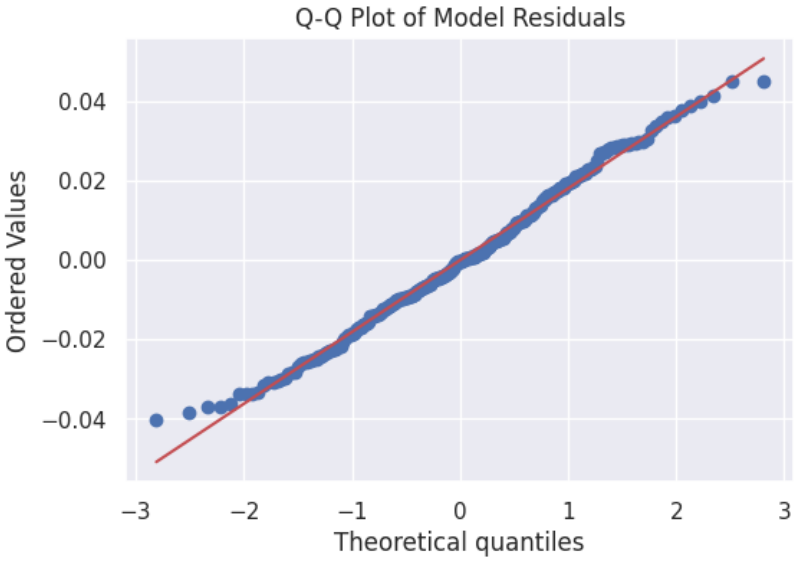
6. Mixd Effects ANOVA for nWBV

Research Question #2: Does nWBV vary across different visit times within individuals?

This line graph with error bars displays the Normalized Whole Brain Volume (nWBV) across two visits for three distinct groups: Nondemented, Demented, and Converted. The blue line represents the first visit, and the orange line represents the second visit. For the Nondemented group, there's a pronounced decrease in mean nWBV between the two visits. The Demented group shows a marked increase from Visit 1 to Visit 2, contrary to what might be expected in the progression of dementia. Interestingly, the Converted group exhibits a substantial decrease from the first to the second visit, which aligns with

expectations if conversion implies a transition from nondemented to demented status. The error bars, indicative of variability or measurement error within each group, are notable for their length in the Converted group at Visit 2, suggesting considerable variation or inconsistency in measurements. The trends in nWBV could reflect underlying pathological changes or differences in the progression of brain atrophy, particularly in the context of dementia conversion. And then we check the assumptions, including homogeneity, sphericity, and normality of this mixed effects ANOVA. As the code shown in the ipynb file and the Q-Q plot shown below, we are confident to say that all three assumptions are satisfied in this analysis.





7. Power Analysis

We also work on statistical power analysis plot for t-tests, and get the results that the minimum sample size is 46.

8. Insights and Conclusion

In conclusion, this analysis set out to explore variations in Estimated Total Intracranial Volume (eTIV) and Normalized Whole Brain Volume (nWBV) across different groups and visits, utilizing a longitudinal dataset to discern patterns potentially indicative of dementia progression. The preliminary data showed gender-based differences in brain volume and cognitive scores, suggesting a nuanced relationship between biological sex and neurological metrics. Subsequent analyses revealed that eTIV and nWBV demonstrate distinct patterns across visits for Nondemented, Demented, and Converted groups.